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Ultra WideBand Wireless Solutions

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MAY 17 2004
FCC - MAILROOM

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
455 Twelfth Street
Room TW-B204
Washington DC, 20554

Re: Ex Parte Communication Concerning Dockets:
ET 98-153
ET 03-108
ET 04-151
ET 02-380
CC 98-146
ET 03-237
ET 00-47
ET 03-121

Through a series of meetings on May 6th 2004 Ex Parte communication occurred between John Santhoff CTO and Steve Moore of Pulse~LINK and Ms. Sheryl Wilkerson, Ms. Jennifer Manner, Mr. Paul Margie, Mr. Barry Ohlson, Mr. Sam Feder, and Commissioner Kevin Martin. During the communication the participants raised issues related to a proposed etiquette for unlicensed communications bands. Specifically a Common Signaling Mode (CSM) for unlicensed communications devices was discussed.

A copy of the presentation and two white papers left with the participants are being filed in the above dockets.

Respectfully,

Steven Moore JD., Ph.D.
Director of Intellectual Property
Pulse~LINK, Inc.

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"When we were young, we wanted to change the world...now we have the technology"™

Justifications for a Common Signaling Mode (CSM)

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Advanced Wireless Communications

Pulse~LINK is an industry leader in Ultra-Wideband (UWB) communications technologies. Formed in 2000, Pulse~LINK has over 130 issued patents and pending applications throughout the world. Pulse~LINK is currently developing UWB communications technologies for wireless and wired media applications. Pulse~LINK is pursuing the convergence of these on a single platform as a Software Defined Cognitive Radio solution. Pulse~LINK is also an early pioneer and proponent of a Common Signaling Mode for UWB and potentially all communications. This paper is directed toward the Common Signaling Mode for wireless communications To date Pulse~LINK is the only company to announce UWB communications on wired media. To obtain information regarding this or other UWB communications technologies please contact Pulse~LINK at the above address.

The world of communications is a dynamic and rapidly changing arena in which technology is constantly evolving. The advent of wireless communication services is just one example of that rapid and dynamic change. Historically there have been a number of difficulties encountered in the wireless communications field. The "Spark Gap" invented in the 1890's by Marconi was capable of broadcasting around the globe Unfortunately for Marconi, by the 1920's the airwaves were beginning to get crowded and "Spark Gap" transmitters did not coexist well with the new frequency based transmitters. As more frequency based transmitters began broadcasting audio the older spark gap transmitters were displaced. Eventually within the United States, the newly formed Federal Communications Commission (FCC) prohibited the use Spark Gap transmitters due to the potential interference issues associated with them.

Worldwide, spectrum is generally apportioned into licensed and unlicensed bands. The concept of an exclusive license is driven by the potential for harmful interference. "Mutual exclusivity is important because it is the statutory trigger as to whether the Commission is required to auction the spectrum."(1) Coexistence is therefore at the very core of Spectrum Management Policy both within the United States and without.

Within the US, the seeds of unlicensed spectrum usage have their root in the 1938 FCC decisions to authorize radio devices to transmit on a sufferance basis (2). Since that time, the FCC has continued to expand the spectrum allocations for unlicensed devices, recently opening up an additional 255 MHz of spectrum bandwidth in the 5.470-5.725 GHz band (3). The spectrum was made available for use by Unlicensed National Information Infrastructure (U-NII) devices, which include Radio Local Area Networks (RLANs), operating under Part 15 of the FCC's rules This move is an example of an attempt to foster the development of new technologies and new capabilities that will serve the public interest. Similar examples exist on a basis as worldwide regulatory bodies attempt to accomplish the same goal of enabling innovation through the use of unlicensed spectrum.

Use of unlicensed spectrum, while sounding relatively simple and benign, is becoming more complex as the number of wireless technologies and users continues to grow. "The unlicensed bands do not provide for any real interference protection or for any exclusive licensee rights to spectrum. Instead, guided by some technical limitations, the bands are open to all comers so long as they operate approved equipment This openness eliminates the entry barrier created by the auction price in the property-like rights model, but creates a different kind of barrier by imposing the more detailed technical rules of the common. In unlicensed bands, users rely on technology to overcome the risk of the traditional tragedy of the commons by engineering their devices so as to avoid any harmful interference."(1) As more and more devices and technologies are developed to take advantage of the unlicensed spectrum, the need for coexistence between systems only increases.

One prime historical example of this type of coexistence conflict is the battle between IEEE 802.11 LAN and Bluetooth, two wireless technologies designed to operate in the unlicensed bands at 2.4 GHz. IEEE 802.11 is a wireless LAN standard that is designed to support data rates of up to 54 Mbps. The 802.11 standards include a number of competing technologies in the same frequency band Bluetooth is a short-range wireless technology designed for personal area networks. Bluetooth operates in the same 2.4 GHz unlicensed band. Since its inception, concerns have been raised over the potential conflicts between Bluetooth and 802.11 LAN technologies. In the US, these concerns have led to consumer hesitation with regards to the Bluetooth technology. For example, Navin Sabharwal states "Bluetooth adoption may be curtailed as network administrators are focused first and foremost on supporting 802.11b."(4) Additionally, fears that Bluetooth technologies might impact existing 802.11 wireless LANs brought an outright denial of the technology from some. "When the first Bluetooth products arrived on the market late last year, many corporate IS managers feared that Bluetooth devices might bring their 802.11b networks to their knees, and some corporate IS directors have issued an outright ban on Bluetooth devices, at least until the interference issues are worked out."(5) In another example, "Dave Rupp is trying to avoid what he calls "chaos-net." As the worldwide manager of local area network (LAN) services for Texas Instruments (TI), he's concerned about the coexistence of wireless RF systems. Specifically, he wants to avoid interference conflicts among devices trying to simultaneously access a Bluetooth personal area network (PAN) and a wireless Ethernet LAN (802.11b)."(6)

The concern about coexistence is not unique to these two technologies, but is actually a subset of the broader concern over spectrum coexistence for technologies utilizing the unlicensed portions of the spectrum. For example, the FCC's ET Docket No. 99-231 was initiated over concerns that a new wireless technology known as HomeRF would interfere with Bluetooth. HomeRF is another wireless networking protocol that is designed to support wireless LANs and voice communications. Docket No. 99-231 was the FCC's response to requests to resolve the potential interference issues between these two technologies by changing the Part 15 rules.

Coexistence issues for wireless communications devices will continue to compound as new devices come to market. "In the near future, it will be commonplace for cell phones to incorporate a variety of interfaces to Bluetooth, UWB, 802.11, GPS, and even TV."(7) This and other types of Advanced Telecommunications devices will have multiple coexistence issues. These issues alone drive the need for some method by which spectrum can be dynamically allocated and shared between disparate wireless technologies or devices. One possible solution to those issues is the concept of a Common Signaling Mode (CSM) by which disparate devices could dynamically allocate bandwidth usage between themselves.

A CSM can provide the mechanism for dynamic link adaptation and regulation of licensed and unlicensed device operation. "The success of the unlicensed approach depends in large part on the Commission's willingness and ability to clearly define the rules that govern the service. This is important if capital, and in turn, services, are to flow to the American people. The threat of the tragedy of the commons is real. And the Commission must recognize that risk and respond accordingly if it is to protect the vital contribution of unlicensed services "(1) If licensed and unlicensed devices implement a CSM, it will allow for significant benefits to all, and would reflect the goals and mission of worldwide regulatory bodies

A Common Signaling Mode for All Wireless Communications Devices

Albert Einstein once said, "we cannot solve our problems with the same thinking we used when we created them."

The Common Signaling Mode (CSM) is a means by which disparate wireless technologies and devices may communicate with each other over a wireless interface. Ideally, it is a "Lowest Common Denominator" wireless mode understandable to all air interfaces. It is a methodology for allowing multiple different Physical layers (PHY) and technologies to coexist in the same spectrum bands and the same physical coverage areas simultaneously while maximizing the scalability and utilization of available spectrum. The CSM could function as a communications channel for cooperative management of allocated PHY resources across the time and frequency domains. In addition the CSM being a highly reliable, robust low-data rate signaling channel, the CSM could offer a wide variety of additional functional capabilities.

Such as:

- A Beacon Timing Channel.
- A Beacon Ranging Channel.
- A Low-data rate communications link for low-bandwidth devices.
- A power conservation functionality for mobile devices.
- A dynamic node-to-node power transmit / receive power control.
- Network status / health / control information.
- A low data rate Over-the-Air-Reprogramming link.
- A low data rate Over-the-Air-Rekeying for Security.
- CSM could be utilized for through-wall imaging systems.
- CSM could be used to support the FCC's Cognitive Radio Initiative.
- It could be used to support the FCC's Interference Temperature Initiative.
- It could be utilized for area security systems.

- The CSM could also enable a "Shut Down" Protocol.
- The CSM could serve as the PHY layer for IEEE 802 15.4a.
- The CSM could be used in a Mesh Network for routing updates.

A primary use of the CSM would be to provide a method for timing synchronization and bandwidth coordination between different wireless technologies utilizing dissimilar Physical layers For example, the use of a CSM could permit two devices, one a wireless device utilizing a spread spectrum approach to Ultra-Wideband (UWB) and the other using an Multi-Band Orthogonal Frequency Division Multiplexing (MB-OFDM) approach to Ultra-Wideband, to negotiate usage of the local spectrum based on a time sharing between the two devices Alternatively the two devices may be a Bluetooth device and an 802.11 device attempting to operate within the same 2.4 GHz spectrum.

The CSM, if properly designed, has the potential to provide a CSM user a number of capabilities and services

<u>a. CSM could provide Beacon Timing Channel</u>

By functioning as an out-of-channel communications mode that all wireless systems are capable of using, the CSM could provide for time synchronization across wireless networks by functioning as a wireless beacon. The concept of beacon signals is not new, they have been used in several different applications For example, IS-95 uses the concept a Pilot Channel (8) in a manner similar to the concept of a beacon. In IS-95, the Pilot Channel is the beacon by which mobile units identify the base station. Part of the CSM packet structure could be designed to support the concepts of a timing beacon and the sharing of time information across wireless networks. By sharing time estimations between wireless devices, it becomes possible to generate highly precise time estimates across the network. Higher time accuracy across the network has the potential to provide for increased capacity, especially in Time Division Multiple Access (TDMA) networks by allowing higher time precision TDMA protocols to be utilized.

<u>b. CSM could provide Beacon Ranging Channel</u>

The CSM could permit an access point to function as a wireless positioning beacon. By allowing an access point to function as a beacon node, positioning applications would become more easily implemented. The concept of a beacon ranging channel is not a new one, it has been used in the Global Positioning System where each satellite acts as a beacon ranging channel. Two-way ranging creates possibilities for even more accurate ranging information. For example, multiple wireless beacon nodes transmitting continual position location information on their own location and estimates of ranges to other devices would enable a mobile device to rapidly determine its location. This would allow indoor E-911 applications to become more readily realizable.

<u>c. CSM could provide Low-Bandwidth communications link for low data rate devices</u>

The CSM could function as a low bandwidth communications channel. Low bandwidth messaging could utilize the CSM; thereby saving bandwidth for users that needed it. For example, a low data rate security sensor need not utilize a high-bandwidth communications link to report its status information, thereby saving that high data rate capacity for applications that needed it. It should be possible to design the CSM packet structure to readily support applications requiring low data rate communications.

d. CSM could provide power conservation functionality for mobile devices

By functioning as a low data rate communications channel, the CSM could enable power conservation in mobile or battery-limited devices. For example, devices requiring a low data rate channel would not need to continuously monitor a high-bandwidth channel to acquire or pass low data rate information. By utilizing the CSM, a mobile device is able to improve its power conservation, thereby ensuring longer operation.

e. CSM could provide dynamic node-to-node power transmit/receive power control

The CSM could be used by wireless links to dynamically control the power transmitted by each end of the link to ensure only the minimum transmit power needed to maintain the link was utilized by each end. This would be advantageous in applications such as mesh networking to ensure that the local RF environment was kept at the minimum level needed to maintain all the links. Additionally, the benefits of transmit power control through a CSM include the potential for a wireless device to take advantage of changing regulatory transmit power limits.[1]

f. CSM could provide network status/health/control information

The CSM could provide additional network functionality. Network status, health and control information could be readily provided over the low data rate, out-of-channel signaling mode the CSM would provide. For example, routing updates on node availability in a wireless mesh network could utilize the CSM instead of occupying a high data rate link.

g CSM could provide a low data rate Over-the-Air-Reprogramming link

Functioning as a low data rate communications link, the CSM could enable on-the-fly software definable radios (SDR) in which the CSM link was used to pass new communications algorithms to the target receiver to enable new waveforms in near real-time. By being able to reprogram a radio over a low data rate communications channel wireless devices could be altered to modify and improve their transmission characteristics or to improve their capacity. As regulations change with respect to software definable radios and other cognitive radios, the CSM may be used to update software and firmware to conform to the new regulations. This Over-the-Air Reprogramming will allow devices to comply with a changing regulatory environment, thereby reducing the cost of redesign and replacement of wireless devices to designers, manufacturers, and consumers alike.

h. CSM could provide a low data rate Over-the-Air-Rekeying

Functioning as a low data rate communications link, the CSM could enable key distribution for secure networks thereby enabling over-the-air-rekeying of encryption devices Security is a major concern in wireless architectures, as well as in communications in general. Encryption is one means of securing a communications link, be it wired or wireless. Secure encryption typically uses encryption keys that need to be changed on a dynamic basis. By creating a low data rate communications

[1] November 12, 2003 the US FCC adopted a Report and Order amending parts 2 and 15 of the Commissions rules regarding U-NII devices in the 5 GHz range This Report and Order specifically required Transmit Power Control to be implemented in devices taking advantage of this frequency allocation

channel, the CSM could enable the wireless rekeying of devices using encryption.

i CSM could be utilized for through-wall imaging systems

CSM could be designed to enable through-wall and ground penetrating radar imaging systems by creating packets that had packet structures or synchronization headers that were fixed in nature and could be utilized as an imaging pulse train. For example, a packet training sequence could be designed to support through-wall imaging systems Using the CSM, the through-wall imaging system need not transmit its own, special pulse sequence, thereby impacting the local radio frequency environment. Instead, perhaps the imaging device could utilize the CSM transmissions from other, near-by devices to complete its through-wall imaging.

j. CSM could be used to support the concept of Cognitive Radios

The IEEE has defined the Cognitive Radio as "a radio frequency transmitter/receiver that is designed to intelligently detect whether a particular segment of the radio spectrum is currently in use, and to jump into (and out of, as necessary) the temporarily unused spectrum very rapidly, without interfering with the transmissions of other authorized users."(9) The FCC has defined Cognitive Radio technologies as those that "make possible more intensive and efficient spectrum use by licensees within their own networks, and by spectrum users sharing spectrum access on a negotiated or an opportunistic basis. These technologies include, among other things, the ability of devices to determine their location, sense spectrum use by neighboring devices, change frequency, adjust output power, and even alter transmission parameters and characteristics."(10) The FCC believes that cognitive radio technologies have the "potential to overcome some of the incompatibilities that exist between various communication services both domestically and worldwide."(10) The CSM could provide a cognitive radio the means by which spectrum negotiations could take place between dissimilar transmitters.

k. CSM could be used to support the concept of Interference Temperature

Another FCC initiative is the concept of Interference Temperature. The FCC's ET Docket No. 03-237 is a request for comments on the concept of a new model for quantifying and managing interference, called Interference Temperature. The FCC hopes this new concept could shift the current method for assessing interference, which is based on transmitter operations, to an approach that is based on the actual RF environment seen by a receiver while simultaneously taking into account the interactions between transmitters and receivers. The interference temperature model represents a fundamental paradigm shift in the FCC's approach to spectrum management by specifying a potentially more accurate measure of interference that takes into account the cumulative effects of all undesired RF energy, from both transmitters and potential noise sources, that is present at a receiver at any instant of time. Utilizing this new measure, the interference temperature limit for the band would serve as an upper bound on the potential RF energy that could be introduced into the band. By changing the current paradigm, the FCC hopes to increase the efficient use of spectrum and ensure coexistence of different wireless systems and technologies. A CSM would support the FCC's concept by creating a signaling channel that could be used by transceivers to communicate information on the local interference temperature. This would allow transceivers to dynamically adjust transmit power based upon the target receiver, thereby ensuring the local interference temperature limit was not exceeded.

l. CSM could be utilized for area security systems

Utilized in an Ultra-Wideband device, the CSM could be designed to enable area security systems, which would utilize the CSM as a radar-like detection signal. By appropriately designing the CSM, it may be possible to develop a packet sequence that could be used to detect motion within the area of the local device. It may be possible for a device to utilize the CSM transmissions from other devices as a detection signal. Such a capability would allow an Ultra-Wideband wireless device to become its own security sensor

m. The CSM could also enable a "Shut Down" Protocol

Wireless devices are not readily accepted in all locations for reasons that vary from security concerns to social reasons. For example, wireless devices are not yet approved for use on airplanes for safety of flight reasons; they are not approved in hospitals for safety of life reasons; and they are typically not desired in movie theaters for social reasons. The CSM could be designed to turn off CSM enabled wireless devices when a CSM device entered such an area.

n. The CSM could serve as the PHY layer for IEEE 802.15.4a

The CSM could function as the IEEE 802.15.4a, Alternate Physical Layer Extension for Low Rate Wireless Personal Area Networks (WPAN), by providing communications and high precision ranging and location capability (with the goal being 1-meter accuracy or better), higher aggregate throughput, and significantly lower power. The 802.15.4a working group has been tasked with defining just such a standard and the concept of a CSM fits right into the existing definition.

o. The CSM could be used in a Mesh Network for routing updates

One problem in mobile mesh networks is the updating of routing information to nodes that are already saturated with traffic. By functioning as a separate, out-of-channel signaling mode, the CSM could provide updated routing information to saturated nodes, thereby permitting them to off-load traffic to different nodes. Additionally, traffic bandwidth would not be used up by common routing information, which would be sent by the CSM instead of occupying a traffic channel.

A Requirement for a Common Signaling Mode in All Wireless Communications Devices Furthers a Number of Worldwide Spectrum Policy Management Goals

Besides supporting the Interference Temperature and Cognitive Radio initiatives as discussed above, a CSM furthers a number of spectrum management objectives. By requiring a CSM for wireless communications devices, the wireless community would be encouraging the highest and best use of spectrum domestically and internationally in order to encourage the growth and rapid deployment of innovative and efficient communications technologies and services, as required by 47 CFR 301 and 303(g). For example, a CSM furthers all general objectives for spectrum defined in the FCC Strategic Plan FY 2003-2008

a. Advance Spectrum Reform by Developing and Implementing Market-

Oriented Allocation and Assignment Reform Policies.

Flexibility of use promotes a market-oriented allocation system. "In a market allocation of spectrum, markets, not central authorities, determine spectrum uses and users. An ideal market allocation should impose no restrictions on spectrum uses and users beyond those necessary to limit interference, to prevent anti-competitive concentration, and to comply with international agreements. Spectrum should not be set aside for federal users or for specific non-federal users such as public safety providers, and public users should be allowed both to sell spectrum and buy spectrum from the private sector. For example, police and fire departments should be able to sell some of their spectrum and use the proceeds to buy new spectrum-conserving radios that could provide greater capacity and interoperability "(11)

An environment wherein a communications device may negotiate a license with a network to use spectrum would require a standard protocol for negotiation of a license This standard protocol should be common to all wireless devices. A CSM is the logical solution to further this objective

b. Vigorously Protect Against Harmful Interference and Enforce Public Safety-Related Rules.

As described above, a CSM enabled device may communicate important parameters to other devices For example, a fixed access point may communicate to each mobile device the location of fixed transceivers and their known transmit powers and potentially their receiver sensitivity. A mobile device within the geographical coverage area of the known fixed transceiver may adjust its power level to prevent interference to the fixed service. Additionally, once a device calculates a local interference temperature it may communicate this information to other devices across a CSM as described above. When operating under a negotiated license within a public safety related frequency band, a CSM would allow the network to send a shutdown command to the device if the network needs to reclaim the spectrum for emergency use.

c. Conduct Effective and Timely Licensing Activities that Encourage Efficient Use of the Spectrum.

Automated licensing in the secondary market will require a standard interaction between a network and a device wishing access to the spectrum. A CSM can provide the protocols for this automated interaction.

d. Provide Adequate Spectrum and Improve Interoperability for Better Public Safety and Commercial Purposes.

A CSM would improve interoperability between all wireless communications devices. Additionally, it provides for automated bandwidth allocation between services. With the addition of interference temperature calculation by the devices and a CSM, public safety and commercial pursuits are better served because the potential for harmful interference to public safety wireless services is mitigated.

Ensuring Guaranteed Throughput

Many competing wireless technologies exist today. They range from cellular telephone systems, to wireless networking systems, to wireless devices used for simple control applications such as a garage door opener. Some of these technologies operate in spectrum that was granted to the technology owner through the granting of a spectrum license, while other technologies operate in spectrum that has been "opened" to all through regulations such as the FCC Part 15 Guidelines for use of "unlicensed" spectrum. Devices and technologies designed to operate in unlicensed spectrum must compete with each other for the use of that spectrum on an interference free basis (12).

Wireless networks are limited in their capacity by Shannon's Law (13), which states the capacity of a communications channel, C, is related to the average signal Power S, the average interfering noise power N, and the bandwidth W as follows:

$$C \le W \log_2\left(1+\frac{S}{N}\right)$$

Shannon's Law imposes a limit on the amount of information any communications channel may pass, and as such, is the absolute best any technology could hope to achieve in information flow. One key point regarding Shannon's Law is that it addresses a single communications channel in which one sender is attempting to pass data to one receiver over a single channel. Networking technologies, be they wired or wireless, are bound by Shannon's Law, but in turn are bounded by the fact that multiple users are attempting to communicate over what is essentially the same channel. This fact places additional burdens upon the communications capacity of a wireless channel. Given the fact that multiple users may at any time need to access the channel, Medium Access Control (MAC) techniques have been developed to ensure that users have equal access to the wireless communications channel. These MAC techniques range from techniques that divide channel access into specific time slots for users such as Time Division Multiple Access (TDMA) techniques, to techniques such as Code Division Multiple Access (CDMA) techniques, which separates user's access to the channel through the application of orthogonal codes. These techniques, as well as the many others that exist, have been created in order to "parse" out the communications channel to all users in as an efficient manner as possible and to permit each user full access to the communications channel.

These MAC techniques are intended to increase the throughput of each wireless user as efficiently as possible by coordinating access to the channel. Because there are typically multiple users attempting to access a wireless channel, a wireless network typically has less total throughput capability than a single communications channel would have. For example, under a Protocol Model of interference for an ad-hoc network, it has been shown that the maximum per-node throughput would be no more than $\frac{C'}{\sqrt{n \log n}}$ bits per second (14). Capacity limitations exist for all wireless networks and are based upon the number of users attempting to access the wireless channel. Given this fact, the best way to maximize this capacity for wireless networks is to ensure cooperation between wireless nodes/users (15). A CSM would provide the means by which users could cooperate in their access of the channel without the need for contention.

Through a common method of negotiation, i.e. a CSM, different wireless technologies or devices could effectively parse out spectrum utilization prior to the act of transmission, thereby attempting to mitigate the impacts of contention within the wireless media. By cooperatively negotiating the use of spectrum, disparate devices would be able to ensure access to spectrum as needed for throughput requirements or guaranteeing quality of service to specific users.

Design Goals for a Wireless CSM

A CSM for all wireless communications devices has the potential to offer a wide range of capabilities to users and to simplify the modernization of spectrum management. Ideally a CSM should incorporate today's technological capabilities, and also be scalable to include other future services and capabilities. At a minimum, the design goals for a **CSM *should include:***

- A timing beacon.
- Information on coarse SYNCH, diversity, frequency acquisition, AGC, channel estimation, and protocol selection
- A mechanism for a low power sleep mode.
- It should enable geo-positioning.
- It should provide for transmit power control
- It should function as a low data rate link when channel conditions won't permit a high data rate link.
- It should address coexistence and interoperability among wireless devices
- It should be low cost to implement.
- The CSM could be implemented as either a mandated RF channel across all wireless communications devices or as an abstraction layer protocol within each technology

Conclusion

The world of wireless communication only continues to grow and expand, with new technologies continually being developed. Thus, the usage of spectrum will only continue to grow as wireless technologies continue to be developed. A Common Signaling Mode (CSM) is a potential method by which disparate wireless technologies could communicate with one another to negotiate the use of spectrum on an interference-free basis. The CSM could be a critical factor in enabling technologies such as cognitive radios and viral communications systems by functioning as a signaling protocol between different wireless communications technologies and systems. By functioning as a "least common denominator" communications link between all wireless systems, a CSM could bring about the full capabilities of technologies such as cognitive radio and viral communications systems and allow a harmonious use of spectrum between different and competing wireless technologies.

Regulatory bodies such as the FCC should require Advanced Telecommunications wireless devices to implement a CSM. By adopting this requirement, regulatory bodies will guarantee everyone access to both licensed and unlicensed wireless spectrum. Additionally, by requiring a CSM in wireless communications devices, new devices currently under development can be brought to market without concerns of coexistence and harmful interference. Finally, use of a CSM allows secondary markets for spectrum to be implemented in a standardized manner allowing more efficient use of this precious worldwide resource.

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Broadband Communications in the Digital Millennium

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1. General Remarks

Pulse~LINK is an industry leader in Ultra-Wideband (UWB) communications technologies. Formed in 2000, Pulse~LINK has over 130 issued patents and pending applications throughout the world. Pulse~LINK is currently developing UWB communications technologies for wireless and wired media applications. Pulse~LINK is pursuing the convergence of these on a single platform as a Software Defined Cognitive Radio solution Pulse~LINK is also an early pioneer and proponent of a Common Signaling Mode for UWB and potentially all communications This paper is directed toward UWB communications on wired media. To date Pulse~LINK is the only company to announce UWB communications on wired media. To obtain information regarding this or other UWB communications technologies please contact Pulse~LINK at the above address."

Essentially, there are three wired media interfaces into most homes, a coaxial connection, a powerline connection, and phone line connections. Traditionally, most of wired media have been utilized to provide services into the home over limited bandwidths The phone lines traditionally carried voice, the power lines were limited to electrical current for the home, and the coaxial connection was used for distribution of content from the cable head-end into the home. Recent developments such as cable modems, DSL and its variants, as well as broadband powerline technologies have changed the way data is communicated into and out of the home. These comments are directed to new developments in high-speed "last mile" applications. Additionally, comments are directed to new in home technologies and architectures that can take advantage of the new developments.

Wired media are generally considered to be band limited channels since the signals supported by most wired media are substantially attenuated at higher frequencies particularly when compared to wireless media. Due to this attenuation, as signals travel greater distances across wired media the bandwidth supported by the media decreases with distance. Many technologies take advantage of the wired media in a home, but typically utilize only a fraction of the bandwidth available to them over the media. For example, voice on a telephone line actually consumes less than 10 KHz of bandwidth even though it has been demonstrated that telephone lines are capable of supporting tens of MHz of bandwidth. Power lines supply AC power at 60 Hertz but have demonstrated similar bandwidths to phone lines in the tens of MHz. Ultra-Wideband is well suited for wired media applications because of its ability to spread its signal energy across the entire available bandwidth of the specific wired media it is being applied to, thereby utilizing the entire available spectrum of wired media.

2. Ultra-Wideband Communications in the Last-Mile

"Last-mile" technologies include (1.) cable modem service, (2) digital subscriber line (DSL); (3) other local exchange carrier provided wireline services; (4) terrestrial fixed wireless service; and (5) satellite service.[1] In a recent Notice of Inquiry the US Federal Communications Commission (FCC) specifically sought comment on new developments in this area. The solicitation for comment addressed technologies such as Wi-Fi, WI-Max, and broadband over powerline.[2] Pulse~LINK is currently developing and in the near term may begin initial deployment of a system involving Ultra-Wideband (UWB) in the last mile.

a. Ultra-Wideband Communications

UWB communications is a fundamental departure from other conventional forms of communications. In most commercial RF communications the signal transmitted and received is a carrier wave. Data is modulated onto the carrier wave at the transmitter and sent through the air to a receiver The receiver demodulates the data from the carrier. In most communications technologies the carrier wave is substantially continuous. In traditional UWB communications there is no carrier wave. A pulse train is generated and modulated with data. The receiver then demodulates the data from the received pulse train.

This impulse nature of UWB communications makes it difficult to classify in conventional communications terms. By communicating with pulses of extremely short duration, the transmitted power may be spread across very wide bandwidths. The current UWB regulations require transmission powers that are within the unintentional emission limit specified in 47 CFR 15. For wireless communications, the frequency band authorized in the US for UWB communications is from 3.1 to 10.6 GHz. According to FCC regulations, to be classified as UWB, the transmitted signal must occupy 20% fractional bandwidth or at least 500 MHz.[3] Because of the extremely low power limitations and very wide bandwidth, UWB has been commonly referred to as a frequency underlay technique A UWB signal may be present at the same frequencies as other conventional "narrowband" services and not produce interference since the UWB signal power in the band of the narrowband service is typically considered within the noise floor.

The Institute of Electrical and Electronic Engineers (IEEE) is currently working on standards for UWB technology in the 802.15.3a working group. Despite not having a final standard agreed upon, a number of companies are developing communications devices utilizing UWB technologies. While most companies in the UWB arena are pursuing Wireless Personal Area Networks (WPAN) devices, and a few looking into Wireless Local Area Network

[1] See Notice of Inquiry, FCC 04-55, Page 9
[2] Id
[3] 2nd Report and Order, In the matter of Ultra-Wideband Communications, FCC Docket 98-153.

(WLAN) devices using UWB, Pulse~LINK is additionally developing UWB solutions for wireline media. The WPAN solutions may be difficult to classify as "last mile" solutions since the target range for these devices is 10 meters. Additionally, the WLAN solutions are targeting 100 meters. UWB over wired media can provide significant bandwidth into and out of the home over substantial distances.

b UWB over CATV architectures

UWB is not just for wireless communications. On June 25th, 2002 Pulse~LINK announced its "wired media" initiatives [4] Historically, wireline communications techniques have migrated to the wireless arena. For UWB the opposite is true Marconi's first transmissions with the "spark gap" transmitter can be thought of as the first UWB radio transmissions. The carrier of Marconi's transmitter was not the frequency based carriers of most modern telecommunications rather they were pulses similar to modern UWB communications. UWB as applied to Hybrid Fiber Coax (HFC) television distribution systems shows promise to increase the bandwidth capacity of the downstream system by as much as 1.2 Gbps, without degradation to the current content of the system. In the upstream UWB has the potential to increase bandwidth by as much as 480 Mbps. This system is in the early stages of development at Pulse~LINK but shows great promise.

Cable television is made possible by the technology of coaxial cable. Rigid coaxial cable has a solid aluminum outer tube and a center conductor of copper-clad aluminum. Flexible coaxial cable's outer conductor is a combination of metal foil and braided wire, with a copper-clad, steel center conductor. The characteristic impedance of the coaxial cable used in cable television is 75 ohms. The well-known principles of transmission line theory apply fully to cable television technology. Modern Cable television distribution networks, HFC networks, employ fiber links from the providers head-end out to nodes located within the neighborhoods serviced. From the node to the customers premises are still wired with coaxial cable. The bandwidth limitation of these systems is the coaxial portion of the system.

The most important characteristic of coaxial cable is its ability to transport in a shielded media spectral content over a broad range of frequencies with relatively low loss (DC to 3GHz+). In essence a separate frequency spectrum of its own, shielded from the outside world. This means that a television receiver connected to a cable signal will behave in a similar manner than if it were connected to an antenna. Since the cable spectrum is tightly sealed inside an aluminum environment (the coax cable), a properly installed and maintained cable system can use frequencies assigned for other purposes in the over-the-air environment. This usage takes place without causing interference to these "Over-the Air" applications that might otherwise co-exist in the same frequency domain. Due to the "Shielded" nature of these signals within the coax cable new spectrum separate from the "Over-the- Air" spectrum is "created" inside the cable. In some cable systems, dual cables bring two of these sealed spectra into the subscriber's home, with each cable containing different signals.

Pulse Link's Ultra Wideband cable technologies increase bandwidth by super-imposing an UWB signal into the existing data signal as illustrated in FIG. 1 and

[4] http.//www pulselink net/pr-june25-2002 html

subsequent recovery of the UWB signal at the set-top box or subscriber gateway. Hence Pulse~LINK technology offers significant bandwidth increases with no modification to the existing network infrastructure.

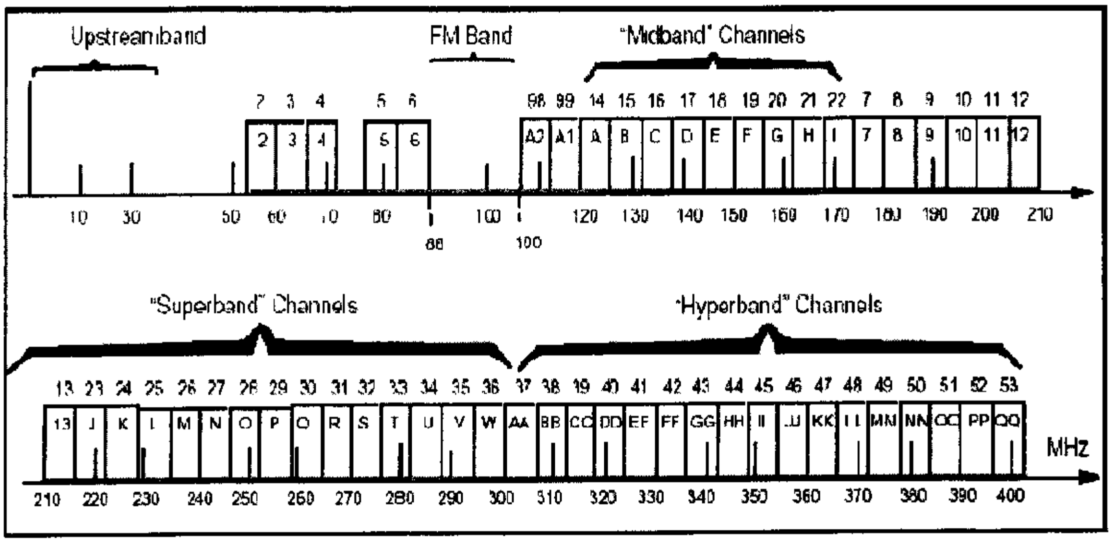

FIG. 1 A Frequency Plan with a UWB signal (green)

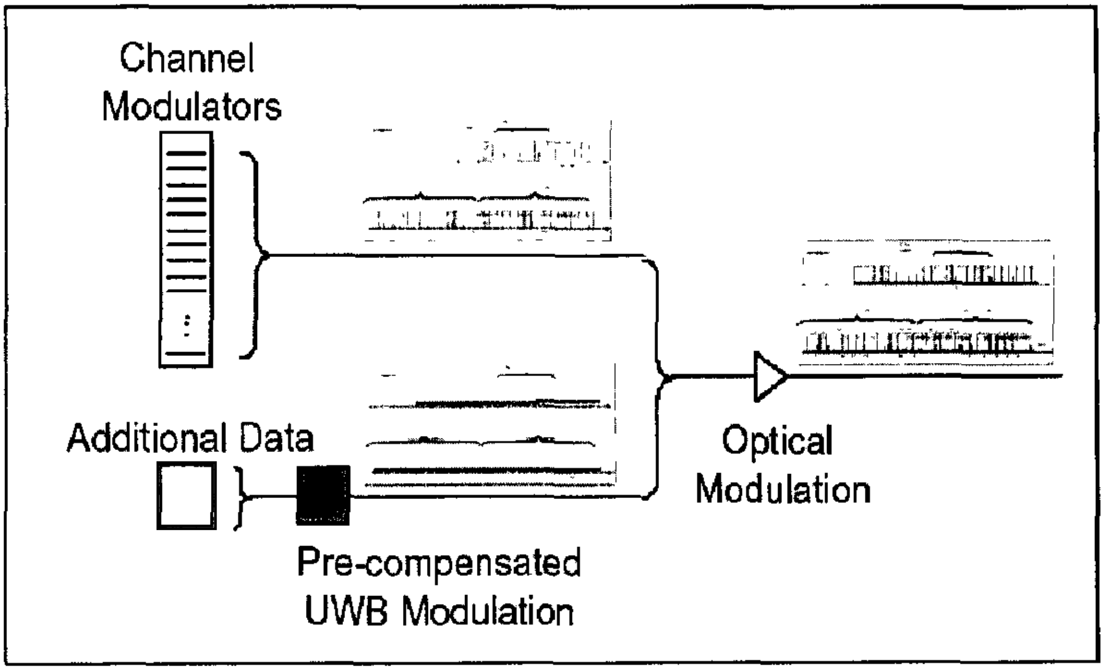

FIG 2 UWB Communications over HFS Distribution Systems

Pulse~LINK's UWB solution for CATV/HFC systems is illustrated in FIG 2. The normal content is modulated into the standard frequency plan employed by the plant operators. Additional data is modulated onto a pre-compensated UWB signal and overlaid onto the signal to be transmitted The combined signal is sent to the HFC distribution through the normal optical modulator. In the customer's premises, the UWB signal content may be extracted by a UWB enabled set top box or home gateway. Pulse~LINK's unique UWB technology is capable of substantially increasing the capacity of most cable systems bearing NTSC, SECAM or PAL signals with NO MODIFICATION to existing infrastructure allowing additional data rates *into the 100's of Mega Bits.* In addition, data rates for the upstream channel can be increased substantially as well enabling bi-directional communication though existing CATV/HFC networks without interfering with *existing channel* content.

c. UWB over Powerline Systems:

"The idea of using the alternating current (AC) power lines to carry information to a variety of devices is not new. A number of devices or systems already use carrier current techniques to couple radio frequency (RF) energy to the AC electrical wiring for purposes of communication. For example, AM radio systems on some school campuses employ carrier current technology;[5] many

[5] Campus radio systems have been operating for over fifty years in the United States at many *universities as unlicensed broadcast radio stations in* the AM Broadcast band Initially, the receiver and signal source were attached to the same electric power line With the advent of the transistor radio,

devices intended for the home, such as intercom systems and remote controls for electrical appliances and lamps also utilize carrier current technology;[6] and for many years, electric utilities have been using carrier current technology to monitor and control the electrical power grid. More recently, these systems have been used to convey information in digital form, providing communications at relatively slow transmission speeds on carrier frequencies below 2 MHz All such devices are subject to our existing Part 15 rules for low-power, unlicensed equipment operating on a non-interference basis.[7,8]

A number of technologies are currently being investigated for power line communications. It is important to note that the current regulatory definition of UWB is a signal that occupies either a 20% fractional bandwidth or a signal that is at least 500 MHz wide. *In wired media applications,* 20% fractional bandwidth may be significantly lower than 500 MHz. For example, in a Hybrid Fiber Coax system a signal may have a center frequency of 400 MHz. To meet the definition of UWB this signal need only occupy 80 MHz (20% fractional bandwidth). In a powerline communications system a signal centered at 20 MHz need only occupy 4 MHz to be considered UWB. This is a substantial departure from wireless UWB where signals can occupy GHz of spectrum, or at a minimum 500 MHz.

Generally, there are three modes of noise most common: Gaussian noise, low voltage impulsive interference, and very high voltage spikes. Of these three, the low voltage impulsive interference tends to be the predominant cause of data transmission errors Therefore, data transmission may be reliably accomplished though power lines even in the presence of Gaussian noise. As for high voltage spikes, they are relatively infrequent and can potentially cause data errors, but with error detection/retransmission (ACK/NACK) being commonly recognized as the best method of recovering the lost information. Furthermore, these characteristics may vary significantly as the electrical power load conditions on the line vary. For example, such electrical load variation may be caused by power draw from virtually any type of electrical device, such as industrial machines, electric motors in household and commercial appliances, light dimmer circuits, heaters, battery chargers, computers, video monitors, audio equipment, and any other device that requires electricity to operate.

Typically, different types of data transmission formats are susceptible to different types of attenuation and distortion. Narrowband transmission formats such as frequency shift keying (FSK) or amplitude shift keying (ASK) are somewhat immune to frequency dependent attenuation, and thus may suffer little or no distortion. However, the entire narrowband signal may fall into an attenuation null and be severely attenuated. Wideband transmission formats such as spread spectrum are less susceptible to the

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the receiver is still able to pick-up enough signal for adequate reception when placed next to the electric power line in a dormitory or other locations on the electric power lines *See* 47 C.F.R § 15 221

6 *See e.g* , X-10 products for home automation at <http.//www X10 com>, and products conforming to ANSI/EIA-600.31-97 *Power Line Physical Layer and Medium Specification* (CEBus Standard)

7 *See* 47 C.F R §§ 15.3(f) & (t), 15.5, 15.31(d), (f), (g) & (h), 15 33(b)(2), 15 107(a)-(c), 15 109(a), (b), (e) & (g), 15.113, 15.201(a), 15 207(c), 15 209(a) and 15.221

8 Notice Of Inquiry, In the Matter of Inquiry Regarding Carrier Current Systems, including Broadband over Power Line Systems FCC Docket 03-104,

signal degradation caused by narrowband attenuation null. However, due to the wider bandwidth associated with a spread spectrum signal, the spread spectrum signal experiences more distortion due to frequency dependent attenuation. Thus, a conventional narrowband signaling format is susceptible to attenuation while a conventional wideband signaling format is more susceptible to distortion.

Another technique employed in Power Line Communications (PLC) is the use of Orthogonal Frequency Division Multiplexing (OFDM). OFDM is a method of digital modulation in which a data stream is split into multiple narrow band channels of contiguous but different frequencies. The standard approach to OFDM is to use the same data allocation to all frequencies, similar to the IEEE 802 11a standard However, while possible this type of data allocation scheme is undesirable in power line media since some frequencies are severely attenuated. A conventional fix to this problem is to allow the transmitter and receiver to adapt to the characteristics of the channel disabling those OFDM carriers where significant attenuation nulls exist But this approach dramatically increases the complexity and cost while simultaneously decreasing the available bandwidth.

Yet another method for transmitting data through power lines is frequency division multiplexing (FDM) and time division multiplexing (TDM). One feature of the present invention is that ultra-wideband (UWB) pulses, or signals can co-exist with either the OFDM or the FDM/TDM approach, thereby increasing the bandwidth of the communication system.

UWB shows great promise for broadband communications over in-home electrical power distribution. Coupling UWB pulse signals to the local in-home power lines, Pulse~LINK has been able to achieve simultaneous symmetrical two-way data rates of 62.5 Mbps in each direction and asymmetrical 100+ Mbps in one direction. Pulse-Link has demonstrated UWB power line communication with streaming video in both uni-directional and bi-directional modes. It is important to note that emissions from broadband signals over power lines have been classified in two ways. "A carrier current system can be designed such that the signals are received by conduction directly from connection to the electric power line (unintentional radiator), or the signals are received over-the-air, due to radiation of the radio frequency signals from the power line (intentional radiator).[9]" The emissions from Pulse~LINK's over power line UWB solution are "unintentional" since the UWB enabled devices are transmitting and receiving signals by conduction directly to and from the power line.

d. UWB over Twisted Pair Wire Media:

UWB signals have additionally been successfully applied to twisted pair media such as phone lines. The bandwidth of this media type is slightly higher but comparable to UWB over power line. UWB over Twisted Pair shares the same characteristics of "unintentional" emission as the powerline since the transmission and reception are directly from the twisted pair line not from "over-the-air". Twisted pair media are made in a number of configurations some shielded and others not shielded. Additionally, twisted pair media are classified by how tightly the individual pair is twisted. Some twisted pair media support higher bandwidths than others. A UWB signal can

[9] *See* 47 C.F.R §§ 15 3(z) and 15 3(o), respectively

be made to occupy the entire available bandwidth of twisted pair media and provide additional capacity to the network.

3. Pulse~LINK's Vision for the Digital Millennium:

Pulse~LINK's vision for broadband services to the American public include an integrated UWB solution. It provides ubiquitous connectivity of all networked consumer electronics and appliances throughout entire home Originating at the CATV/HFC head end, additional content can be provided into the customer's premises. The additional content is modulated onto a UWB signal that is then superimposed onto the conventional frequency plan for CATV distribution At the customers premises the signal can be received by a UWB enabled home gateway. This gateway is additionally enabled to distribute the content throughout the home via the installed power lines, phone lines or wirelessly. Devices requesting content make the request through any UWB enabled connected media from the home gateway. The gateway can then make the request from the CATV/HFC head-end via a UWB signal in the upstream. This Bridged Ultra-WideBand Architecture (BUWBA) allows a UWB enabled device in the home or customer premises to be serviced directly from the head-end.

This vision allows for a number of unique advantages. The UWB enabled home gateway may determine over which media to route the content to the requesting device based on network traffic, current wireline noise conditions, priority and quality of service requirements to name a few. Additionally, since the individual requesting device has a unique identifier, such as a MAC address or device ID the CATV head-end is capable of delivering that digital content in an end-to-end secure delivery system. This secure system is capable of providing Digital Rights Management (DRM) across the entire system from the CATV headend directly into the consumer's home and to a specific device. Pulse~LINK is rapidly moving toward realizing this vision.

The vision includes an integrated chipset that supports communications across wireless, and wireline media. Additionally, since Pulse~LINK's chipset, currently under development, has a wide variety of software and firmware re-programmability, and interfaces to a wide range of media. This ability allows Pulse~LINK to provide a seamless user experience to the consumer who will not have to worry about how to route digital data to which media type or bandwidth requirements or whether they have the latest version. UWB Wireless LAN, UWB CATV, UWB Powerline, and UWB twisted pair communications can all be supported from a single chipset. A true software defined cognitive radio for both wired and wireless Medias. Pulse~LINK has working discrete prototypes and is expecting tape-out of a fully functional test chip by years end.

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Pulse~LINK™

May 6, 2004

The Vision

An Integrated Inexpensive Chipset Solution Delivering:

- Up to [illegible] Gigabit New Data Capacity over existing wired infrastructures

Presentation Outline

- Related FCC Dockets
- The need for a Common Signaling Mode (CSM)
- Features, Benefits, and Future Uses of a CSM
- A Roadmap for a CSM in Unlicensed Devices
- Conclusion

Related Dockets

This presentation relates to the following dockets.
Appropriate copies will be filed in each.

- ET 98-153 Ultra-Wideband
- ET 03-108 Cognitive Radio
- ET 04-151 3650-3700 MHz band
- ET 02-380 Additional spectrum for Unlicensed Devices (3GHz)
- CC 98-146 Advanced Telecommunications to all Americans.
- ET 03-237 Interference Temperature
- ET 00-47 Software Definable Radios
- ET 03-122 UNII Devices in the 5GHz band

The Need for a Common Signaling Mode (CSM)

- Historically Unlicensed Spectrum has been a open to all.
  - 2.4 GHz Unlicensed band has multiple competing technologies
  - 802.11, Bluetooth, cordless phones, etc… all compete for spectrum
  - The potential for interference between these devices is real.
- New devices are being developed that will be able to utilize spectrum more efficiently
  - Cognitive Radios will sense their surrounding RF environment prior to transmission.
  - Software Definable Radios will have the ability to adapt to under utilized bands.
  - Ultra-Wideband devices will overlay signals into occupied bands.
- Dissimilar technologies can be designed to cooperate with one another.
  - UWB devices can coexist with licensed services in the same frequency band more efficiently.
  - Employing a CSM devices may take advantage of disparate technologies.
- Hybrid or Multi-Mode Devices are under development that will need to share data between technologies.
  - "In the near future, it will be commonplace for cell phones to incorporate a variety of interfaces to Bluetooth, UWB, 802.11, GPS, and even TV." Texas Instruments
  - These devices would need to share data not just at the logical level but at the spectrum level as well.

The Need for a Common Signaling Mode (CSM)

- A number of Dockets address issues that a CSM can perform.
  - Cognitive Radios (ET-03-108) could pass information on the RF environment to any enabled device through a CSM.
  - Local Interference Temperature (ET-237) calculations can be shared through a CSM.
  - Software Definable Radios (ET-0047) can communicate with network access points through a CSM.
  - A device can exchange transmit power settings (ET 03-122) across a CSM allowing for greater ranges in rural environments.
  - Devices can use a CSM to notify each other to vacate a frequency channel (ET-03-122) when necessary.
  - A CSM can allow disparate UWB (ET 98-153) implementations to coexist.
  - The CSM provides a method for device identification signaling (ET 04-151, ET 02-380, ET 98-237).
  - By providing a mechanism for ensured interoperability, a CSM promotes the development of new advanced communications technologies (FCC 98-146)

The Need for a Common Signaling Mode (CSM)

- A CSM Furthers a Number of the Commissions Objectives as defined by the Strategic Plan FY 2003-2008.
  - A CSM can assist in the transition to a Market-Oriented Allocation by providing a standard mechanism for dynamic re-use of spectrum in the secondary market.
  - A CSM with a "shut-down" feature assists the vigorous protection of public safety spectrum uses.
  - A CSM provides a standard mechanism for automated secondary market licensure, promoting efficient use of spectrum
  - A CSM can guarantee interoperability for better public safety and commercial purposes.
  - A CSM can allow dissimilar UWB (ET 98-153) implementations to coexist.

The Need for a Common Signaling Mode (CSM)

- Unlicensed Spectrum without a CSM
  - Inefficient Use of Spectrum
  - Limited Scalability
  - No guaranteed Quality of Service (QOS)
  - Commercial Viability of new Technology is Questionable.
- Unlicensed Spectrum with a CSM
  - Maximizes the Efficient Use of Spectrum
  - Maximizes Scalability
  - Enables QOS guarantee
  - Maximizes Commercial Viability Since Interoperability, Scalability, and Guaranteed QOS Allow Consumers to be Confident in New Technologies

Features, Benefits, and Future Uses of a CSM

- The uses of a CSM are Many, Some may include:
  - A Beacon Timing Channel.
  - A Beacon Ranging Channel.
  - A Low-Bandwidth communications link for low-bandwidth devices.
  - A power conservation functionality for mobile devices.
  - A dynamic node-to-node power transmit/receive power control.
  - Network status/health/control information.
  - A low-bandwidth Over-the-Air-Reprogramming link.
  - A low-bandwidth Over-the-Air-Rekeying.
  - CSM could be utilized for through-wall imaging systems.
  - It could be utilized for area security systems.
  - The CSM could also enable a "Shut Down" Protocol.
  - The CSM could serve as the PHY layer for sensor networks.
  - The CSM could be used in a Mesh Network for routing updates.
  - Allows for new regulatory changes to be implemented without device replacement as a software update.

A Roadmap for a CSM in Unlicensed Devices

- The Commission Should Adopt a Multi-Tiered Deployment Strategy for CSM.
  - Ultra-Wideband Physical Layer Standards Still In Progress
  - Cognitive Radio Technologies Should Employ a CSM
  - Software Definable Radio Technologies Should Have a CSM
  - New Emerging Technologies Should be Designed Up Front With A CSM
- Second Tier Should Require all Devices to Implement a CSM.
  - Can be a Common RF Channel Similar to NPRM 04-151
  - Removes Interoperability Concerns From the Consumers.
  - Similar to the "Plug and Play" Concept

Conclusion

- A CSM resolves many regulatory issues currently being addressed by the Commission.
- A CSM for wireless communications devices is in the public's interest.
- A CSM provides a standard mechanism for future spectrum management.
- A CSM provides for stability to industry which will further the development of Advanced Telecommunications Services.
- A CSM removes interoperability concerns from consumers allowing for increased commercial viability.
- The Commission should mandate a CSM for UWB and all future unlicensed allocations.
- The CSM can be extended to legacy unlicensed systems over time.